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Response of different soybean genotypes against soybean stem fly, *Melanagromyza sojae* (Zehntner)

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Abstract
Fifteen genotypes of soybean were screened against stem fly, *Melanagromyza sojae* during Kharif 2018 and 2019. At flowering stage of soybean crop the lowest stem fly infestation was recorded in the genotypes RSC-1046 and NRC-94 followed by MACS-1520, MACS-1201, NRC-127, DS-3105, SL-1104. The maximum stem fly infestation was noticed in genotype VLS-89. At harvest, the genotype NRC-94 had recorded the lowest stem fly infestation followed by RSC-1046, MACS-1520, MACS-1340 and NRC-127. At flowering stage, the genotype NRC-94 had recorded the lowest stem tunneling due to stem fly and it was significantly superior over all the genotypes. The highest stem tunneling was recorded in PS-1572. At harvest of soybean crop, the minimum stem tunneling due to stem fly was noticed in the genotype NRC-94 followed by RSC-1046 and MACS-1520. The genotypes MACS-1340 and NRC-127 were also found quite promising in exhibiting the minimum stem tunneling. The genotypes VLS-89, SL-1104 and PS-1572 were found to be comparatively inferior in minimizing stem tunneling due to stem fly at harvest.

Keywords: Soybean, stem fly, plant infestation, tunnelling, *Melanagromyza sojae*

Introduction
Soybean, (*Glycine max* (L.) Merril) has become second most important Kharif crop in Vidarbha after cotton playing a key role in synergizing the economy of the region. Soybean belong to the family of leguminaceae. It is well known as oilseed and pulse crop which is richest and cheapest source of high-quality mineral, protein, vitamin and fat. It is unique crop with high nutritional value. It supplies most of the nutritional constituents essential for human growth. Hence, soybean is called as "wonder crop", "golden crop" or "miracle crop". (Nannaware *et al*. 2018) [5]. In nutritious point of view, it is an excellent source of protein and oil. It is a two-dimensional crop as it contains about 40 to 42 % high quality protein and 20 to 22 % oil (Motaphale *et al*. 2017) [3].

The maggot of *M. sojae* enters the stem through the leaf petiole, feeds on the stem pith by mining both upwards and downwards and makes a reddish coloured tunnel in the affected plant (Van den Berg, 1998) [13]. Infestations in the early crop growth stages cause high seedling mortality and thus reduce the crop stand. Infestations during later growth stages do not kill the damaged plants, however, they may significantly affect the yield-attributing characters of the plant, e.g. reduction in plant height, number of branches per plant, number of trifoliate leaves, leaf area per plant and dry matter accumulation (Savajji, 2006) [8].

Indiscriminate use of chemicals in soybean plant protection has led to the problems like pest resurgence, pest outbreak and development of resistance to insecticides, elimination of natural enemies, risks to human and animal health, besides environmental pollution (Rao *et al*. 2000) [7]. However, the limitations of chemical control measures have necessitated to exploring the most eco-friendly method of pest control by developing pest resistant varieties, use of eco-friendly insecticides of plant and animal origin.

Material and methods
Fifteen soybean genotypes were obtained from All India Coordinated Research Project on Soybean, Vasantarao Naik Marathwada Krishi Vidyapeeth, Parbhani for field evaluation to find out the genotypic resistance to the soybean stem fly *M. sojae*.

The high yielding genotypes with tolerant/resistant, property could further be used in developing commercial varieties or explored directly for further adoption in the pest problematic areas.

The field experiment was carried out at Department of Entomology, Akola Each soybean genotype was sown in three rows of 5 meter length with a spacing of 30 X 10 cm in each replication. All the agronomic practices including fertilizer dose (30:75:30 kg NPK/ha) were followed in establishing the plants except the plant protection measures.
Observations on stem fly incidence and stem tunneling due to stem fly at flowering and harvest stage of soybean crop were recorded and percentage was worked out.

Results and Discussion

The pooled results indicated the lowest stem fly incidence was noticed in the genotypes RSC-1046 and NRC-94 to the extent of 15.00 per cent each and they were followed by the genotypes MACS-1520 (17.50 per cent), MACS-1201, NRC-127 and DS-3105 (22.50 per cent each) and SL-1104 (25.00 per cent) and these seven genotypes were found to be statistically at par with each other (Table 1). However, of these, the genotypes *viz*., RSC-1046 and NRC-94 were found to be significantly superior over all the remaining genotypes except MACS-1520, MACS-1201, NRC-127, DS-3105 and SL-1104 which were further found to be at par with genotypes JS-335 and PS-1572 that exhibited the stem fly incidence to the tune of 27.50 per cent each. These two genotypes, JS-335 and PS-1572 were further found to be at par with the genotypes JS-2071, MACS-1340 and DSB-32 which observed stem fly incidence of 30.00 per cent each and genotypes JS-2053 and KDS-921 which exhibited stem fly incidence to the extent of 32.50 per cent each and the genotype VLS-89 that recorded the highest stem fly incidence to the tune of 37.50 per cent.
It is observed clearly from the above findings that the soybean genotypes RSC-1046 and NRC-94 had consistently exerted the desirable impact against stem fly. Thus, they emerged as the promising genotypes in minimizing the stem fly incidence. Similarly, genotype MACS-1520 also consistently performed well and appeared as the next best genotype against the stem fly infestation.
The data on the reaction of various soybean genotypes against stem tunneling at flowering stage evidenced that the stem tunneling inflicted by stem fly ranged between 3.12 to 9.26 per cent (Table 1). All the genotypes were found to be significantly superior over genotype PS-1572. The genotype NRC-94 had observed the lowest stem tunneling to the tune of 3.12 per cent and it was found to be significantly superior over all the genotypes screened. The next best genotype RSC-1046 accounted the stem tunneling to the extent of 4.25 per cent and it appeared to be significantly superior over rest of the genotypes except MACS-1520 (4.42 %) and MACS-1340 (4.91 %) to which it was found to be at par.
The genotype NRC-127 had noticed the stem tunneling of 5.29 per cent and it was found to be statistically similar with the preceding genotypes MACS-1520 and MACS-1340, at the same time it was further found to be statistically at par with genotypes JS-2071, MACS-1201, DS-3105, JS-335, JS-2053 and KDS-921 which accounted the stem tunneling to the extent of 5.72, 5.85, 5.91, 5.93, 6.10 and 6.36 per cent, respectively. Of these, except NRC-127, all these genotypes were further found to be at par with the DSB-32 that exhibited the stem tunneling to the extent of 6.54 per cent. Of the remaining genotypes, SL-1104 and VLS-89 measured the stem tunneling to the tune of 7.14 and 7.78 per cent, respectively and both the genotypes were found to be at par with each other. Of these, genotype SL-1104 was found statistically equal with its preceding genotypes *viz*., JS-2053, KDS-921 and DSB-32. Whereas, the highest stem tunneling of 9.26 per cent was recorded in the genotype PS-1572.
Thus, considering the above results, it could be stated that, among the fifteen genotypes screened against stem tunneling due to stem fly at flowering stage for the two successive years, the soybean genotypes NRC-94, RSC-1046 and MACS-1520 were found most reactive in consistently keeping the stem fly tunneling at minimum level as compared to check variety JS-335 and other genotypes.

Table 1: Response of soybean genotypes against stem fly (%) and stem tunneling (%) at flowering during Kharif 2018 and 2019.

Sr. No.	Genotypes	Plant infestation (%) at flowering		Mean	Stem tunneling (%) during flowering		Mean
		2018	2019		2018	2019	
1.	PS 1572	25.00 (29.89) abc	30.00 (33.21) bc	27.50 (31.60) bcd	8.87 (2.98) h	9.65 (3.10) h	9.26 (3.04) i
2.	MACS 1201	25.00 (29.89) abc	20.00 (25.82) ab	22.50 (28.28) abc	6.12 (2.47) efg	5.58 (2.36) cde	5.85 (2.42) def
3.	MACS 1340	25.00 (29.89) abc	35.00 (36.22) bc	30.00 (33.14) cd	5.03 (2.24) c	4.79 (2.19) bcd	4.91 (2.22) bcd
4.	MACS 1520	20.00 (26.56) ab	15.00 (22.50) a	17.50 (24.68) ab	4.82 (2.19) c	4.02 (2.00) ab	4.42 (2.10) bc
5.	KDS 921	40.00 (39.23) d	25.00 (29.89) abc	32.50 (34.62) cd	5.99 (2.45) def	6.73 (2.59) efg	6.36 (2.52) efg
6.	DSB 32	30.00 (33.21) bcd	30.00 (33.211) bc	30.00 (33.21) cd	6.14 (2.48) fg	6.94 (2.63) efg	6.54 (2.56) fg
7.	NRC 94	15.00 (22.50) a	15.00 (22.50) a	15.00 (22.79) a	2.92 (1.71) a	3.32 (1.82) a	3.12 (1.76) a
8.	NRC 127	20.00 (26.56) ab	25.00 (29.89) abc	22.50 (28.28) abc	4.85 (2.20) c	5.73 (2.39) cde	5.29 (2.30) cde
9.	DS 3105	20.00 (26.56) ab	25.00 (29.89) abc	22.50 (28.28) abc	5.26 (2.29) cde	6.55 (2.56) efg	5.91 (2.43) def
10.	VLS 89	35.00 (36.22) cd	40.00 (39.23) c	37.50 (37.75) d	8.17 (2.86) h	7.39 (2.72) g	7.78 (2.79) h
11.	SL 1104	30.00 (33.21) bcd	20.00 (26.56) ab	25.00 (29.89) abc	6.98 (2.64) g	7.30 (2.70) fg	7.14 (2.67) gh
12.	RSC 1046	15.00 (22.50) a	15.00 (22.50) a	15.00 (22.79) a	3.92 (1.98) b	4.58 (2.13) bc	4.25 (2.06) b
13.	JS 2071	25.00 (29.89) abc	35.00 (36.22) bc	30.00 (33.14) cd	5.14 (2.27) cd	6.30 (2.51) efg	5.72 (2.39) def
14.	JS 2053	25.00 (29.88) abc	40.00 (39.23) c	32.50 (34.62) cd	6.29 (2.51) fg	5.91 (2.43) def	6.10 (2.47) efg
15.	JS 335 (Check)	30.00 (33.21) bcd	25.00 (29.89) abc	27.50 (31.60) bcd	6.11 (2.48) efg	5.75 (2.40) cde	5.93 (2.43) def
	SE (m) ±	2.64	3.44	2.56	0.05	0.09	0.07
	CD at 5 %	8.00	10.43	7.77	0.18	0.28	0.22
	C.V. %	12.45	15.98	11.95	3.60	5.29	4.36

Note: Figures in parentheses are arc sine transformed values and $\sqrt{n}$ values for stem fly infestation and stem tunnelling due to stem fly, respectively

The lowest incidence of stem fly at harvest was registered in the genotype NRC-94 to the tune of 37.50 per cent, followed by the genotypes RSC-1046, MACS-1520, MACS-1340 and NRC-127 which exhibited the stem fly incidence to the extent of 42.50, 45.00, 50.00 and 50.00 per cent, respectively and all these five genotypes were found to be statistically at par with each other. However, of these, genotype, NRC-94 was found to significantly superior over other ten remaining genotypes

(Table 2).

The genotypes *viz*., JS-2071, MACS-1201 and JS-335 noticed the stem fly incidence to the extent of 57.50, 57.50 and 60.00 per cent respectively and they were at par with each other. These genotypes had also exerted statistically similar impact with the preceding genotypes *viz*., RSC-1046, MACS-1520, MACS-1340 and NRC-127. The variety JS-335 was found to be at par with the rest of the genotypes *viz*., KDS-921, PS-1572, DS-3105, VLS-89, JS-2053, SL-1104 and DSB-32 which exhibited the stem fly incidence to the extent of 65.00, 65.00, 65.00, 67.50, 67.50, 70.00 and 75.00 per cent, respectively.

During the investigation, the stem fly infestation at flowering stage of the soybean crop ranged between 15.00 to 40.00 per cent with the pooled average ranging from 15.00 to 37.50 per cent. Whereas, at harvest stage the average stem fly infestation ranged between 35 to 85 per cent with the pooled average of 37.50 to 75.00 per cent. Out of fifteen genotypes screened the genotypes NRC-94, RSC-1046, MACS-1520, MACS-1340 and NRC-127 had exhibited the comparatively less infestation than other genotypes.

Also, the other genotypes *viz*., MACS-1340, NRC-127, JS-2071 and MACS-1201 also performed well against stem fly incidence as compared to JS-335.

The national check JS-335 was almost similar effective as above genotypes noting the stem fly infestation in the range of 25 to 30 per cent with average of 27.5 per cent at flowering. Whereas, it showed the stem fly infestation in the range of 55 to 65 per cent with pooled average of 60 per cent at harvest. From the above results it could be inferred that the genotypes NRC-94, RSC-1046 and MACS-1520 were appeared to be promising in having the minimum stem fly incidence both at flowering stage and harvesting stage of soybean crop.

The earlier researcher, Rajashekar *et al*. (2020) [6] observed the lowest stem fly infestation of 13.82 per cent in variety JS-335, as against the maximum per cent stem fly damage RSC-1046 (26.32 %) which are in contradictory with the findings of the investigation which shows the superiority of genotype RSC-1046 in minimizing the stem fly infestation as compared to JS-335. Shete *et al*. (2019) [9] reported the lower stem fly infestation in the genotypes KDS-1045 (35 %), KDS-921 (35 %) and JS-335 (40 %) as compared to the maximum infestation in the range of 45 to 70 % in rest of the other genotypes at flowering. The lowest stem fly infestation (65.00 %) was recorded in JS-335, JS-97-52 and KDS-1045. Whereas, the remaining genotypes observed the stem fly infestation in the range of 70 to 95 % at harvesting stage. Jadhav *et al*. (2013) [2] screened thirty-seven genotypes and observed stem fly infestation in the range of 20.5 to 42.11 per cent at flowering stage. Out of these genotypes NRC-55, NRC-52 and NRC-51 had noted less stem fly incidence in the minimum range of 20.05 to 22.49 per cent and DSB-101 (21.34 %), DSB-102 (23.93 %) as against the check JS-335 (35.25 %). At harvesting stage, stem fly infestation was observed in the range of 23.37 to 44.87 %. The minimum stem fly infestation in the range of 23.37 to 24.87 was observed in NRC-55, NRC-52 and NRC-51 as against 36.50 % in check variety JS-335.

During the investigation check variety JS-335 had observed the average stem fly incidence 27.50 per cent during flowering, while, 60 % during harvest stage. Thus, these findings are supported by Jadhav *et al*. (2013) [2]. Similarly, Upadhyay (2017) [12] had screened ten genotypes and observed the stem fly infestation in the range of 0 to 40 per cent at 30 DAS and in the range of 60 to 100 per cent at maturity stage which agreed the level of stem fly infestation as observed in the investigation.

The data on the reaction of various soybean genotypes on stem tunneling due to stem fly at harvest evidenced that the stem tunneling was found in the range of 10.22 to 23.16 per cent amongst various genotypes (Table 2).

The minimum stem tunneling to the extent of 10.22 per cent was registered in the genotype NRC-94, it was followed by the genotypes RSC-1046 (11.76 %) and MACS-1520 (11.98 %) and these three genotypes were found to be statistically at par with each other. Of these, genotype NRC-94 was found significantly superior over all the genotypes except RSC-1046 and MACS-1520 which were further found to be at par with the genotypes MACS-1340 and NRC-127 noticed the stem tunneling to the tune of 12.80 and 13.55 per cent, respectively. The genotypes MACS-1340 and NRC-127 were further found at par with MACS-1201 which noticed the stem tunneling of 14.38 per cent and found at par with genotype JS-2071 that accounted the stem tunneling of 14.99 per cent.

Table 2: Response of soybean genotypes against stem fly (%) and stem tunneling (%) at harvesting during Kharif 2018 and 2019.

Sr. No.	Genotypes	Plant infestation (%) at harvest		Mean	Stem tunneling (%) during harvest		Mean
		2018	2019		2018	2019	
1.	PS 1572	70.00 (57.10) cd	60.00 (50.89) bcde	65.00 (53.78) cde	21.55 (4.64) def	24.77 (4.97) g	23.16 (4.81) f
2.	MACS 1201	60.00 (50.89) abc	55.00 (47.88) abcd	57.50 (49.32) bcd	15.03 (3.87) bc	13.73 (3.70) b	14.38 (3.79) cd
3.	MACS 1340	40.00 (39.10) a	60.00 (50.77) bcde	50.00 (45.00) abc	11.95 (3.46) ab	13.65 (3.69) b	12.80 (3.56) bc
4.	MACS 1520	45.00 (42.12) ab	45.00 (42.12) abc	45.00 (42.13) ab	11.78 (3.43) ab	12.18 (3.49) ab	11.98 (3.46) ab
5.	KDS 921	60.00 (50.89) abc	70.00 (57.10) de	65.00 (53.78) cde	20.16 (4.49) def	19.14 (4.37) de	19.65 (4.43) e
6.	DSB 32	85.00 (67.50) d	65.00 (53.77) cde	75.00 (60.47) e	19.97 (4.46) def	18.65 (4.32) de	19.31 (4.39) e
7.	NRC 94	40.00 (39.23) a	35.00 (36.22) a	37.50 (37.75) a	10.53 (3.24) a	9.91 (3.15) a	10.22 (3.20) a
8.	NRC 127	60.00 (50.89) abc	40.00 (39.23) ab	50.00 (45.00) abc	12.98 (3.60) ab	14.12 (3.75) b	13.55 (3.68) bcd
9.	DS 3105	60.00 (50.77) abc	70.00 (57.10) de	65.00 (53.78) cde	19.23 (4.38) de	17.51 (7.18) cd	18.37 (4.28) e
10.	VLS 89	70.00 (57.10) cd	65.00 (53.78) cde	67.50 (55.26) cde	24.27 (4.92) f	21.12 (4.59) ef	22.70 (4.76) f
11.	SL 1104	65.00 (53.78) bcd	75.00 (61.17) e	70.00 (56.86) de	22.98 (4.79) ef	23.26 (4.82) fg	23.12 (4.81) f
12.	RSC 1046	40.00 (39.10) a	45.00 (42.12) abc	42.50 (40.68) ab	10.98 (3.31) a	12.54 (3.54) b	11.76 (3.43) ab
13.	JS 2071	55.00 (47.88) abc	60.00 (50.77) bcde	57.50 (49.32) bcd	15.11 (3.89) bc	14.87 (3.85) bc	14.99 (3.87) d
14.	JS 2053	75.00 (60.11) cd	60.00 (50.77) bcde	67.50 (55.38) cde	17.95 (4.23) cd	18.79 (4.33) de	18.37 (4.29) e
15.	JS 335 (Check)	55.00 (47.88) abc	65.00 (53.78) cde	60.00 (50.79) bcde	18.07 (4.25) cd	17.83 (4.22) d	17.95 (4.24) e
	SE (m) ±	4.72	4.22	3.67	0.15	0.12	0.09
	CD at 5 %	14.32	12.80	11.13	0.46	0.36	0.28
	C.V. %	13.27	11.98	10.40	5.24	4.09	3.23

Note: Figures in parentheses are arc sine transformed values and $\sqrt{n}$ values for stem fly infestation and stem tunnelling due to stem fly, respectively.

The genotypes RSC-1046, MACS-1520, MACS-1340, NRC-127, MACS-1201 and JS-2071 were significantly superior over all rest of the genotypes. The other genotypes *viz*., JS-335, DS-3105, JS-2053, DSB-32 and KDS-921 had recorded the stem tunneling to the tune of 17.95, 18.37, 18.37, 19.31 and 19.65 per cent, respectively and they remained statistically at par with each other and significantly superior over the remaining genotypes. The genotypes *viz*., VLS-89, SL-1104 and PS-1572 had recorded comparatively higher stem tunneling to the extent of 22.70, 23.12 and 23.16 per cent, respectively and they were at par with each other.

Thus, it is observed from the above results that the genotypes NRC-94, RSC-1046 and MACS-1520 had consistently recorded the minimum stem tunneling due to stem fly as compared to the other genotypes, hence, they emerged as the most promising genotypes against stem tunneling due to stem fly and performed well in the keeping stem tunneling at minimum level at harvest stage of the soybean crop. Also, among other genotypes, MACS-1340, NRC-127, MACS-1201 and JS-2071 had also exerted good impact against stem tunneling and appeared superior to that of national check JS-335. However, JS-335 (Check variety) was found comparatively better than rest of the genotypes *viz*., DS-3105, JS-2053, DSB-32, KDS-921, VLS-89, SL-1104 and PS-1572. Of these, genotypes VLS-89, SL-1104 and pS-1572 were inferior in minimizing stem tunneling.

The findings of the investigation as regard to stem tunneling on soybean seedlings, induced due to stem fly infestation revealed that stem tunneling in various soybean genotypes was observed in the range of 3.12 to 9.26 per cent at flowering and 10.22 to 23.16 per cent at harvest stage of soybean crop. The genotypes NRC-94, RSC-1046 and MACS-1520 had consistently observed the minimum stem tunneling at flowering (3.12 %, 4.25 % and 4.42 %) as well as harvesting (10.22 %, 11.76 % and 11.98 %), whereas, genotype PS-1572, SL-1104 and VLS-89 observed comparatively more stem tunneling. The check variety JS-335 had accounted moderate stem tunneling of 5.93 and 17.95 per cent stem tunneling at flowering and harvest stage of crop, respectively. The findings of the investigation as regard to the reaction of different genotypes on stem tunneling are discussed with in light of the views of early researchers as below, Jadhav *et al*. (2013) [2] screened thirty seven genotypes and observed lower stem tunneling in the genotypes, NRC-55 (11.25 %), DSB-101 (11.72 %), NRC-51 (11.81 %), NRC-52 (12.48 %) and DSb-102 (13.18 %) at flowering stage of crop as against the highest stem tunneling in MACS-2001 (28.93 %), KHSB-2 (28.60 %), whereas, lower stem tunneling was recorded in NRC-55 (13.31), DSB-101 (14.36 %), NRC-51 (14.57 %), NRC-52 (14.93 %) and as against highest stem tunneling in KHSb-2 (33.37 %) at harvest. The check variety JS-335 had shown the medium stem tunneling of 23.50 per cent and 22.12 per cent, respectively during flowering and harvest stage of soybean crop. Azmi and Sharma (2020) [1] had screened about 51 genotypes and they observed the stem tunneling in the range of 13.02 to 74.17 per cent. The check variety JS-335 had noticed the medium stem tunneling of 27.62 %.

Nagendra (2019) [4] screened sixteen genotypes and recorded stem tunneling in the range 6.45 to 21.00 per cent at 30 DAG and in the range of 9.94 to 24.51 per cent at maturity. In this study the check variety JS-335 had registered the medium stem tunneling of 13.18 % at 30 DAG and 18.43 % at maturity stage. Similarly, the genotypes MACS-1520 had counted the stem tunneling to 19.90% to 24.38%, respectively at 30 DAG and maturity stage. Upadhyay (2017) [12] tested ten genotypes and observed stem tunneling in the range of 0 to 7.95 % at 30 DAS and in the range of 4.67 % to 20.82 % at maturity stage. Taware *et al*. (2008) [10] had studied the sixteen genotypes against the stem tunneling due to stem fly and reported the stem tunneling in the range of 6.55 to 35.53 per cent in Kharif 2005 and 1.68 to 40.64 per cent in Kharif 2006. The variety JS-335, one of the checks observed the stem tunneling 22.15 % and 21.49 % during 2005 and 2006, respectively. Taware *et al*. (2004) [11] screened 107 elite soybean genotypes in the three years 1998, 2000 and 2002 and observed the stem tunneling in the range of 2.20 to 46.51 % during 1998, 10.51 to 46.83 % in year 2000 and in the range of 9.58 to 53.30 % during 2002. Thus, these research workers are in the agreement with the finding of investigation as regard to the percentage of stem tunneling due to stem fly damage to soybean seedlings.

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